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DARK FOCUS:

INTERSUBJECT VARIATION, INTRASUBJECT
STABILITY, AND RELATIONSHIP TO NEAR RETINOSCOPY

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NAVAL AEROSPACE MEDICAL RESEARCH LABORATORY
PENSACOLA FLORIDA

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SUMMARY PAGE

THE PROBLEM

Previous studies have shown that dark focus varies between individuals while remaining relatively fixed over time. These relationships were quantified in a population of future naval aircrewmembers to determine whether or not individual variability exists in a group who have met stringent visual screening requirements.

In addition, it has been reported that near retinoscopy, a clinical measure, is a means to determine dark focus that may be used by clinicians. The relationship between near retinoscopic values and dark focus measures needed further study.

FINDINGS

Dark focus exhibited intersubject variation and intra-subject stability in a population of future naval aircrewmembers. Because dark focus is correlated with empty field myopia, it could have potential in screening aviators for susceptibility to empty field myopia and their ability to detect air-to-air targets.

Near retinoscopy was found to be correlated with dark focus, but further study is needed to define the relationship.

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INTRODUCTION

When the retina is stimulated by light, the lens adjusts focus, i.e., accommodates, to provide a clear image of an object on the retina. However, accommodation does not always provide for focusing of an object perfectly in the plane of the retina, particularly when luminance is low or little detail exists in the visual field. Under these conditions, accommodation lapses toward a state referred to as the dark focus. Shifts towards the dark focus also occur when the eye views an unstructured lighted field. The regression of accommodation to the dark focus value in the dark and in empty visual fields is termed functional myopia because, for most observers, the dark focus value is closer than their far point of accommodation. As may be expected, the dark focus has been shown to be predictive of the degree of empty-field myopia an individual will manifest.

The dark focus value can be measured with the laser-Badal optometer. This instrument measures the accommodative status of an individual without itself influencing the person's accommodative state (1).

Values for the dark focus reported in the literature vary (Figure 1), but generally have a mean between one diopter (D) and 2D for groups, and wide variation between individuals (2,3,4,5,6,7). Dark focus is reasonably consistent in individuals over periods ranging from several hours to a year (5,6,8). The wide individual differences but relatively stable values for a given individual over time suggest that the dark focus is an individual trait.

This study was designed to determine the inter- and intrasubject relationships between dark focus data values obtained from future naval aircrew members, as well as to evaluate a simpler method of determining the dark focus using a more clinically common instrument, the retinoscope. Using a laser-Badal optometer, several experiments were conducted to determine intersubject differences and intrasubject stability in dark focus values. Since the dark focus was reported to be highly correlated with near retinoscopic values (9), an experiment was designed and conducted to examine further this relationship in our population of aircrewmembers.

PROCEDURE

APPARATUS

The laser-Badal optometer (Figure 2) consists of a stimulus assembly, a shutter/lens assembly, and a chinrest/headrest assembly. The stimulus assembly is mounted on a leadscrew traverse mechanism which adjusts the optical distance of the laser speckle pattern. The stimulus assembly is made up of a 1.0 mW HeNe laser (632.8 nm), a diverging lens, a plane mirror, and a slowly rotating drum (1 rpm). The coherent light from the laser

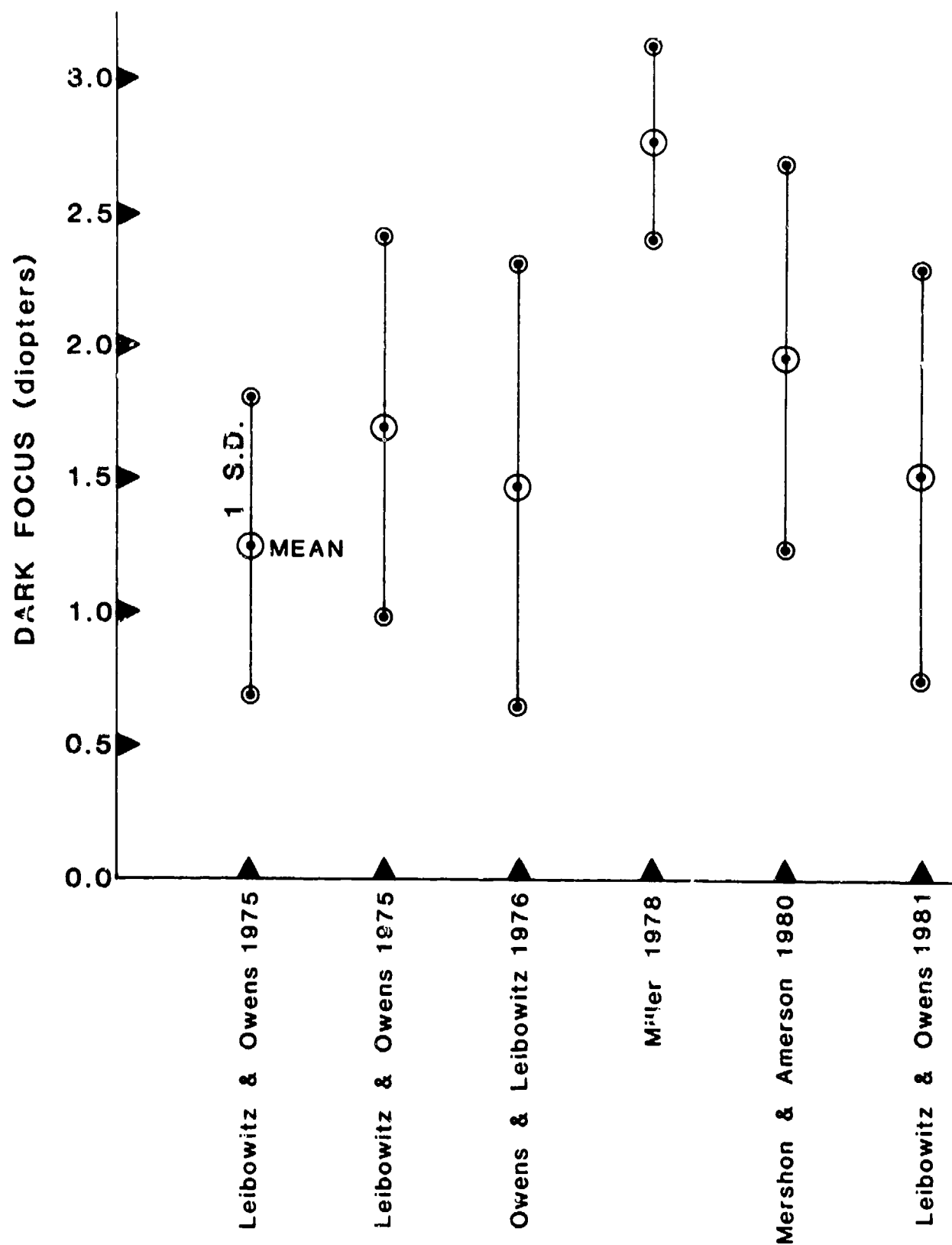


Figure 1

A survey of reported values for dark focus.

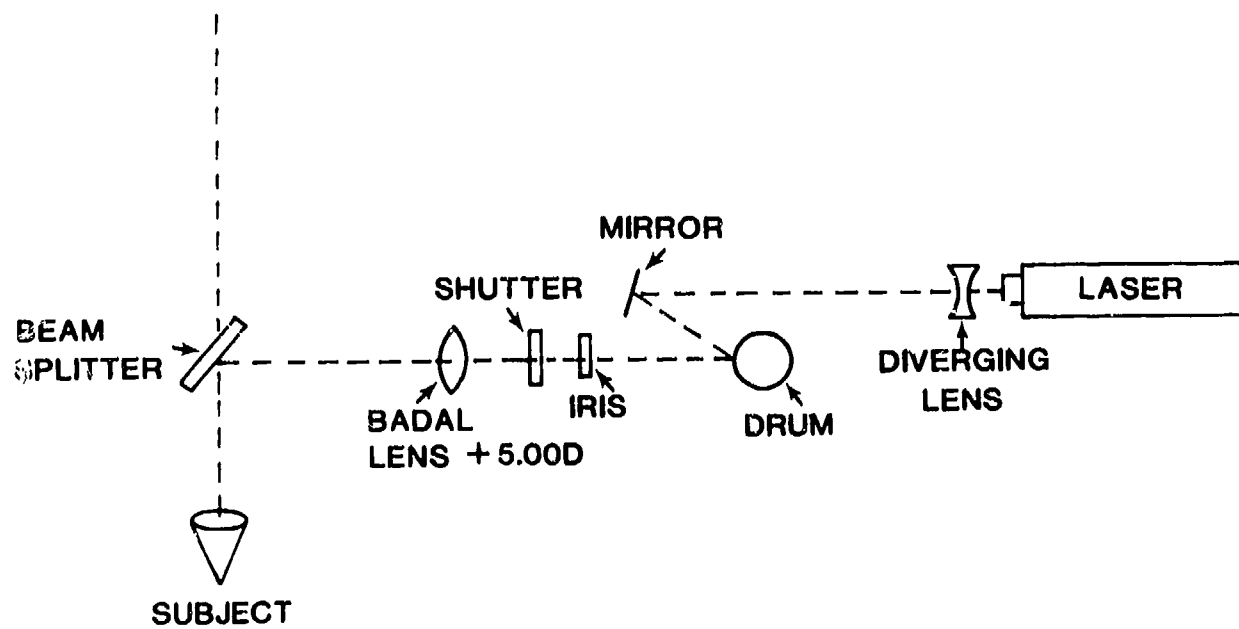


Figure 2
Laser-Badel optometer.

is diverged by the lens and reflected by the mirror onto the rotating drum. The speckle produced on the drum is the stimulus observed by the subject. The shutter/lens assembly consists of a +5.00D Badal lens, a shutter, an iris, and a beam splitter. The shutter controls the exposure time of the speckle pattern. The iris controls the size of the pattern. These components are mounted such that their optical axes correspond both to that of the Badal lens and to the optical path from the eye to the speckle target. The beam splitter is mounted at a 45° angle to the optical axis of the system to allow the speckle pattern to be interposed on the field of view of the subject. The subject's head is positioned by an adjustable chinrest so that his eye is at the focal point of the Badal lens and the speckle pattern is centered in his field of view.

METHOD

The laser-Badal optometer was used to measure the dark focus state of accommodation in each experiment. Prior to each measurement, the speckle pattern was superimposed into the subject's field of view for familiarization and the laser drum was moved through its range to allow the subject to observe upward and downward motion of the speckle pattern, as well as the point of reversal of motion of the pattern. After at least two minutes of dark adaptation, the point of reversal was located by a bracketing method in which the stimulus was relocated repeatedly and the pattern was exposed for 0.5 seconds at each position. The position of the stimulus when reversal was observed was found several times and the mean position of reversal for each subject was calculated. Stimulus position was converted to a dioptric value for the dark focus accommodation of the eye using a conversion based on the Badal principle (see Appendix A for details of the conversion).

A series of experiments has been conducted to examine the dark focus in detail. These experiments addressed intersubject differences in dark focus, repeatability of the measure, and possible relationships between dark focus and mean retinoscopic measures.

In Experiment I, intersubject variation was examined in a group of 12 student Naval Flight Officers. All had acuity of 20/20 or were correctable to 20/20 with conventional spectacles. Six values for the dark focus accommodation were found for each of the men by use of the laser-Badal optometer, and individual means were calculated.

Experiment II examined intrasubject variation in the dark focus. The dark focus for six subjects was determined. Each subject was assigned the mean of six consecutive dark focus determinations as his test value. Four of the subjects were retested approximately one week later.

In Experiment III, dark focus variations were examined among 12 aviators. Dark focus was measured for each man and nine of the aviators were retested 2-4 weeks after their initial tests.

In Experiment IV, the dark focus values of 17 subjects were determined. Twelve of these subjects also underwent retinoscopic examination using the near retinoscopic technique developed by Owens (9). The subjects were instructed to fixate the light in the retinoscope monocularly during the examination. The examination was conducted in a darkened room with the retinoscope held 67 cm from the subject's eye.

RESULTS

Data from Experiment I (Table I) show a wide range of individual values about the mean value of 1.45D (N=12). Individual dark focus values ranged from 0.70 - 2.71D.

TABLE I

Dark Focus Data for Experiment I

SUBJECT	DARK FOCUS	σ
1	0.88	.08
2	1.95	.11
3	1.14	.04
4	0.70	.40
5	2.71	.49
6	0.77	.14
7	2.05	.19
8	1.91	.45
9	1.72	.11
10	1.44	.12
11	0.90	.14
12	1.32	.09
Mean	1.45	.20
σ	0.62	.16

The subjects in Experiment II (Table II) also exhibited a wide range of dark focus values for both the test and retest. However, the test and retest data for each individual were highly correlated ($r=0.95$). A scatter diagram of the test and retest data (Figure 3) shows that the data were repeatable between the test and retest, although the retest dark focus values were consistently greater than those of the initial test. If the test and retest values were identical, they would fall on the dashed line shown in the figure.

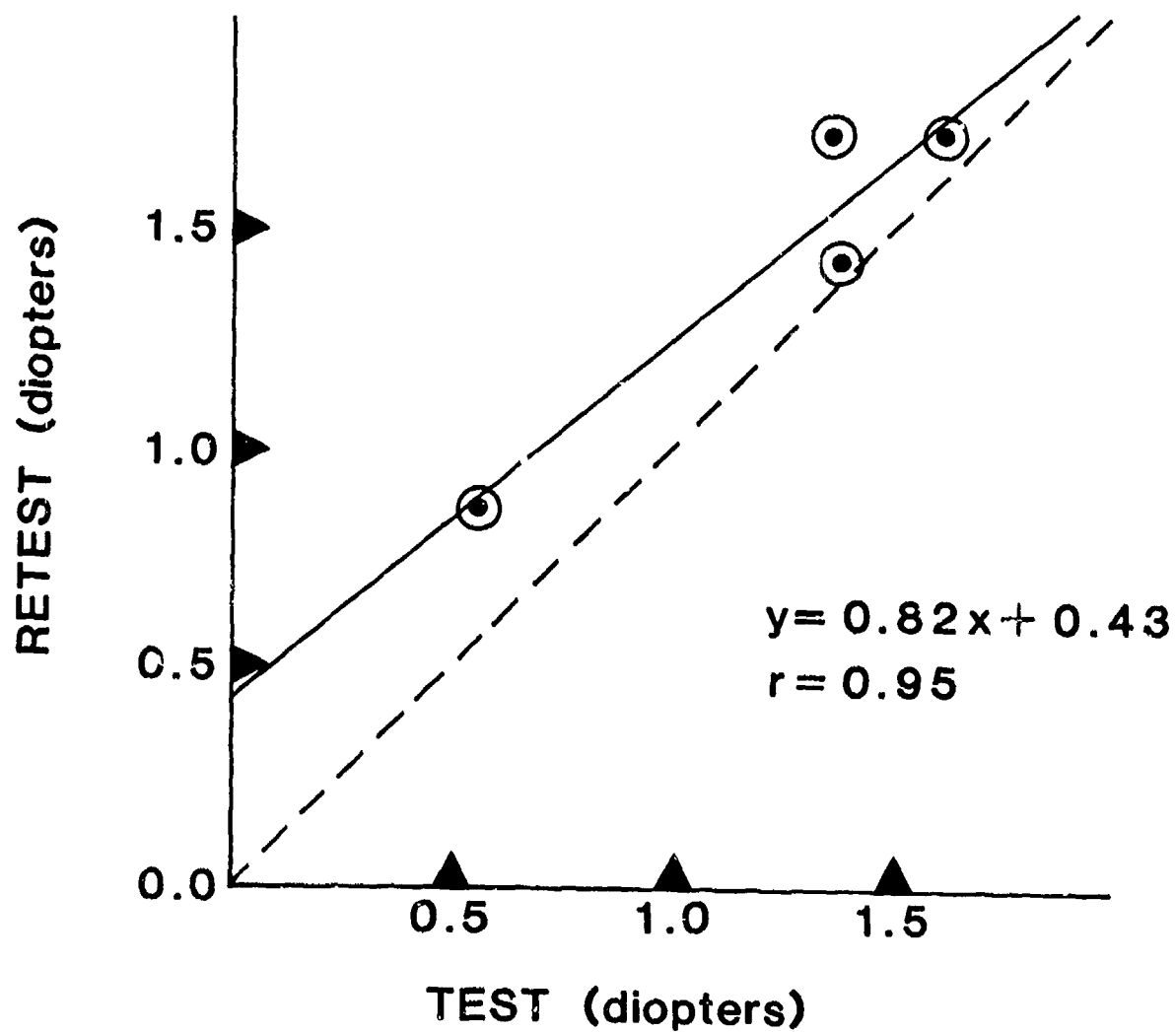


Figure 3

Intrasubject repeatability of dark focus (N=4).

TABLE II

Test and Retest Measures of Dark Focus for Experiment II

SUBJECT	DARK FOCUS	
	Test	Retest
1	1.67	--
2	1.39	1.44
3	1.36	1.72
4	0.56	0.87
5	0.54	--
6	1.62	1.72
Mean	1.19	1.43
σ	0.51	0.40

In Experiment III, intersubject variability was again noted (Table III). A scatter diagram (Figure 4) shows that test and retest data were highly correlated ($r=0.92$), with retest values of dark focus generally greater than initial test values.

TABLE III

Test and Retest Measures of Dark Focus for Experiment III

SUBJECT	DARK FOCUS	
	Test	Retest
1	0.39	0.69
2	0.48	1.40
3	0.13	0.39
4	1.53	2.55
5	1.61	--
6	0.63	0.96
7	-0.17	-0.03
8	-0.17	0.48
10	0.61	0.41
13	1.27	--
14	1.52	2.21
15	1.51	--
Mean	0.78	1.01
σ	0.68	0.88

The individual dark focus values spanned a wide range in Experiment IV (Table IV). Near retinoscopy was performed on twelve subjects and the resulting values ranged from -1.00D to +1.00D with a mean near plano. A scatter diagram comparing the dark focus to the near retinoscopic value for each subject (Figure 5) shows a correlation ($r=-.63$) between the two measures. The inverse correlation is a result of the dark focus value's

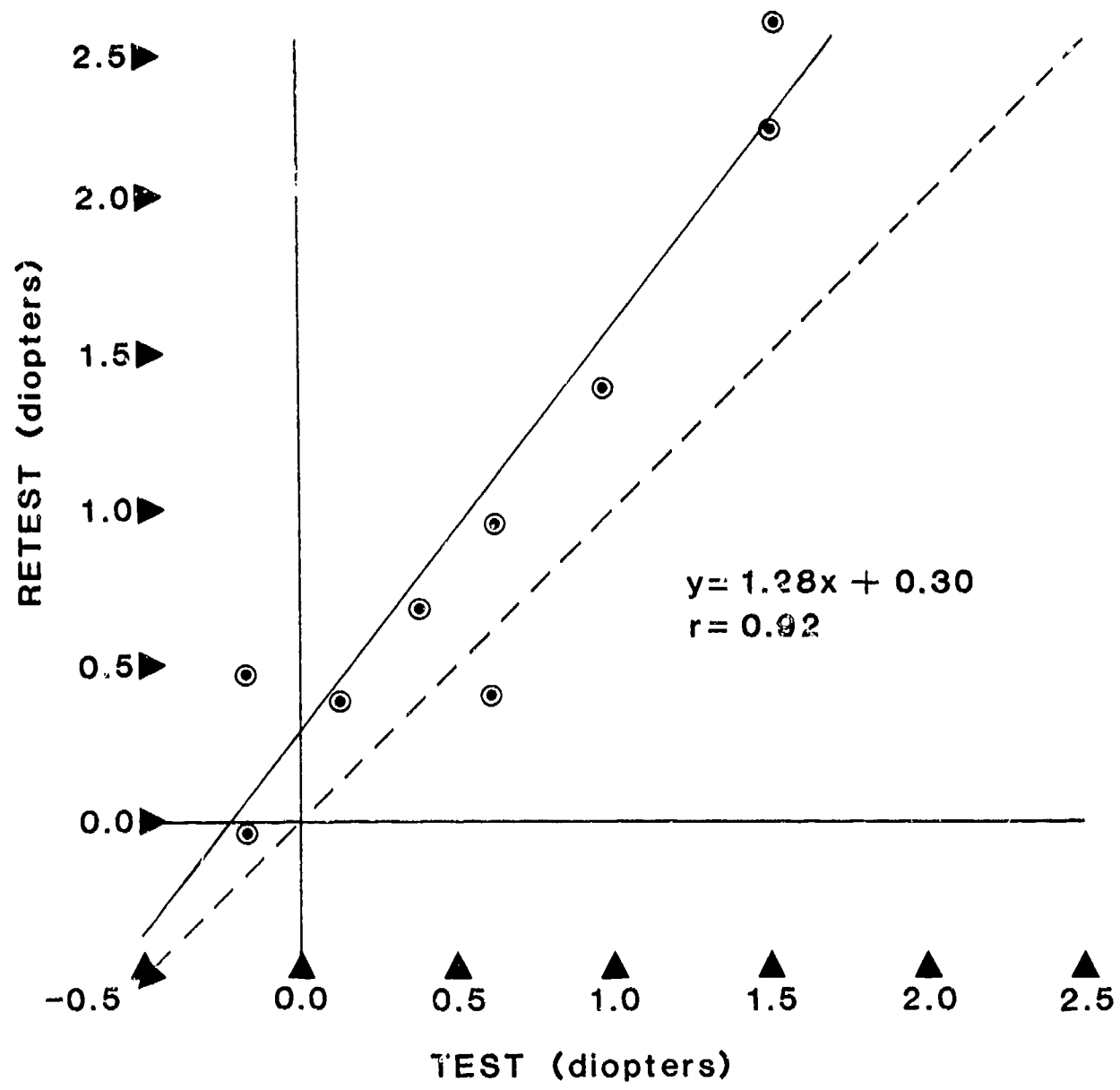


Figure 4

Intersubject variability of the dark focus (N=9).

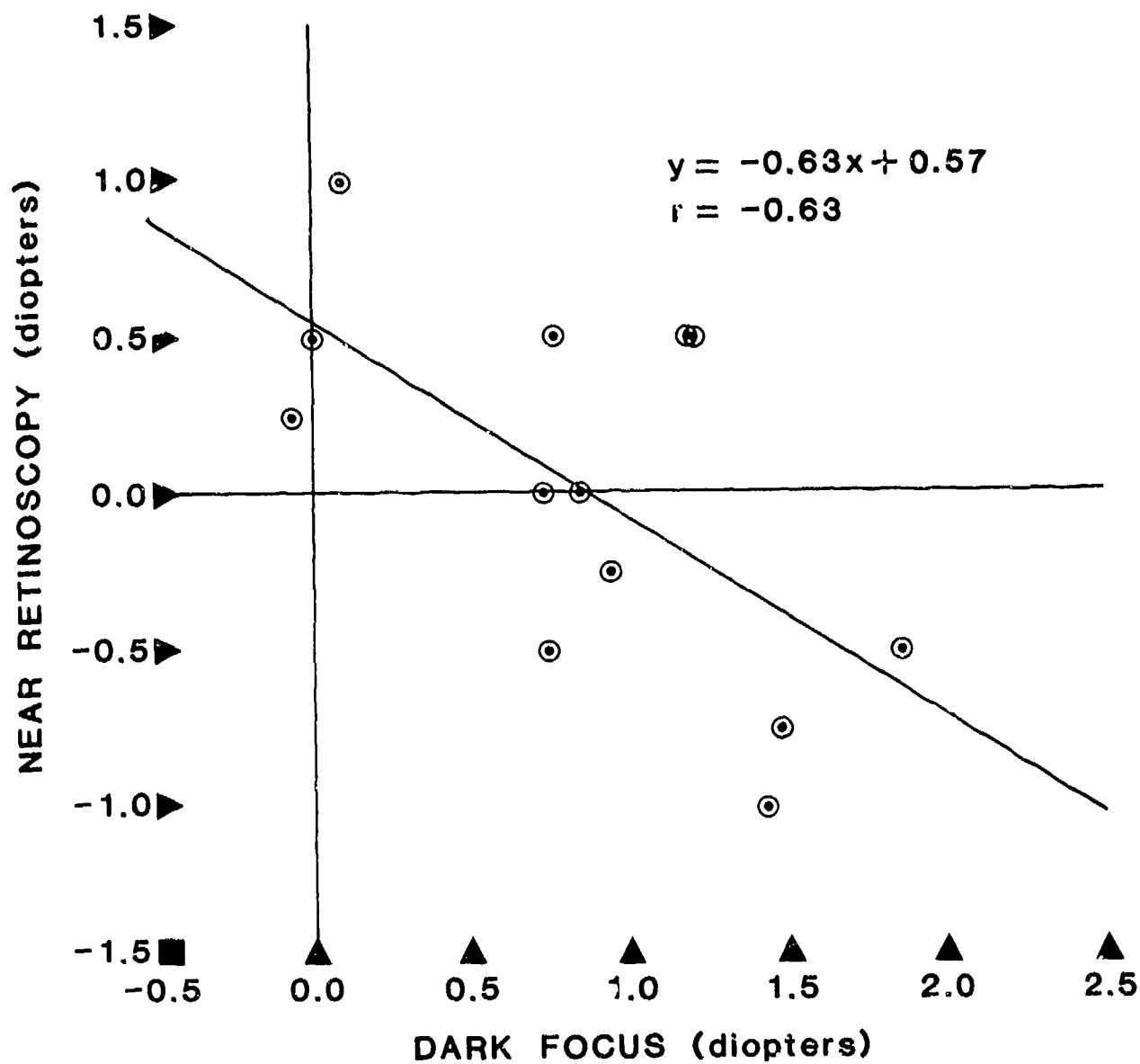


Figure 5

Relationship between dark focus and near retinoscopy (N=12).

reciprocal relationship with the myopia it induces (e.g., if dark focus equals 1D, -1D of night myopia might be expected).

TABLE IV

Dark Focus and Retinoscopy for Experiment IV

SUBJECT	DARK FOCUS	NEAR RETINOSCOPY
1	0.72	--
2	0.75	-0.50
3	1.20	0.50
4	0.95	-0.25
5	0.74	0.00
6	0.10	1.00
7	1.86	-0.50
8	1.21	0.50
9	0.77	0.50
10	0.85	0.00
11	1.48	-0.75
12	1.44	-1.00
13	1.01	--
14	1.46	--
15	1.10	--
16	-0.06	--
17	0.00	0.50
Mean	0.91	0.02
σ	0.53	0.59

DISCUSSION

Previous work in the field of dark focus measurement (2,3,4,5,6,7) has suggested great individual variability in dark focus values. The current data substantiates this suggestion. However, the group means of our dark focus data have been well below the means reported by other investigators. A possible explanation for these lower values is the difference in the subject population tested in this study versus other studies. The subjects used in the current experiments had been accepted into the naval aviation community, and thereby had been prescreened with rigid visual requirements. They are, therefore, different as a group from subject populations drawn from the general public.

Another possible explanation for the lower values is that the subject's accommodative state prior to testing may have influenced their dark focus measurement. It has been postulated that dark focus is not an absolute discrete measurement, but exists as a zone of values depending on the accommodative state prior to measurement (10). This may account for the low values recorded in Experiment III, in which dark focus was measured

after roughly 3 hours of visual testing at predominately 5.5m (18 ft.).

The current study supports the view that dark focus is a reasonably stable trait in individuals. Previous work describing stability of dark focus over time (5,6,8) and our strong test-retest correlations confirm the stability of the dark focus. The test-retest scatter diagrams (Figures 5 and 7) show that the measurement was reliable and repeatable over time periods of several hours to several weeks. The reason for the slight displacement of the regression lines from the ideal ($y=x$) is unknown, but possible causes could include small changes in optometer calibration, administration of test and retest by different experimenters or environmental factors such as time of day, etc.

The work of Owens et al, (9) relating near retinoscopy to the dark focus was supported by the current data. These data indicated that near retinoscopic measurements are correlated ($r=0.68$) with the dark focus. If the relationship between these two measures can be closely determined, retinoscopy could be suggested as a clinical tool for determining dark focus. This would be advantageous because the retinoscope is more widely available, easy to maintain, compact, and familiar to clinicians than is the laser-Badal optometer.

This study indicates that the dark focus is an individual and relatively stable trait. The correlation of dark focus to functional myopias induced by low accommodative stimulation (2) suggests that dark focus measurement may have potential as a method for determining the susceptibility of an individual to myopia induced by degradation of the visual field. These results indicate that further investigation in dark focus is warranted. Areas of future inquiry might include an investigation of the influence of pretest dark adaptation time on the dark focus value obtained, and the effects of physiological and psychological factors (such as stress and fatigue) on dark focus measurements. The feasibility of using the retinoscope as a clinical tool for dark focus determination should be further investigated as well.

In conclusion, dark focus seems to be a clinically determinable entity with potential importance in the screening of people for work in visually unstructured environments. As aviators are routinely subjected to these unstructured visual fields (night flying, high altitude flight), dark focus may be of particular import in assessing suitability for aviation duty. Further testing is necessary to substantiate and quantify the importance of dark focus in the prediction of performance in unstructured visual environments.

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APPENDIX A

Computation of Dark Focus Value Using Badal Principle

Computation of Dark Focus Value Using Badal Principle

By applying the Badal principle to the laser optometer and by using a +5.00 diopter lens as the Badal lens, the short displacement range of the target drum has been optically transformed to a range from near zero to beyond infinity.

The drum is at optical infinity when it is at the focal point of the Badal lens (20 cm for a +5.00 diopter lens).

The Badal formula may be stated

$$Q = F^2 d - F \quad (1)$$

where

Q = the optical distance of the drum from the subject's eye in diopters.

F = the power of the Badal lens in diopters.

d = the distance between the Badal lens and the drum in meters.

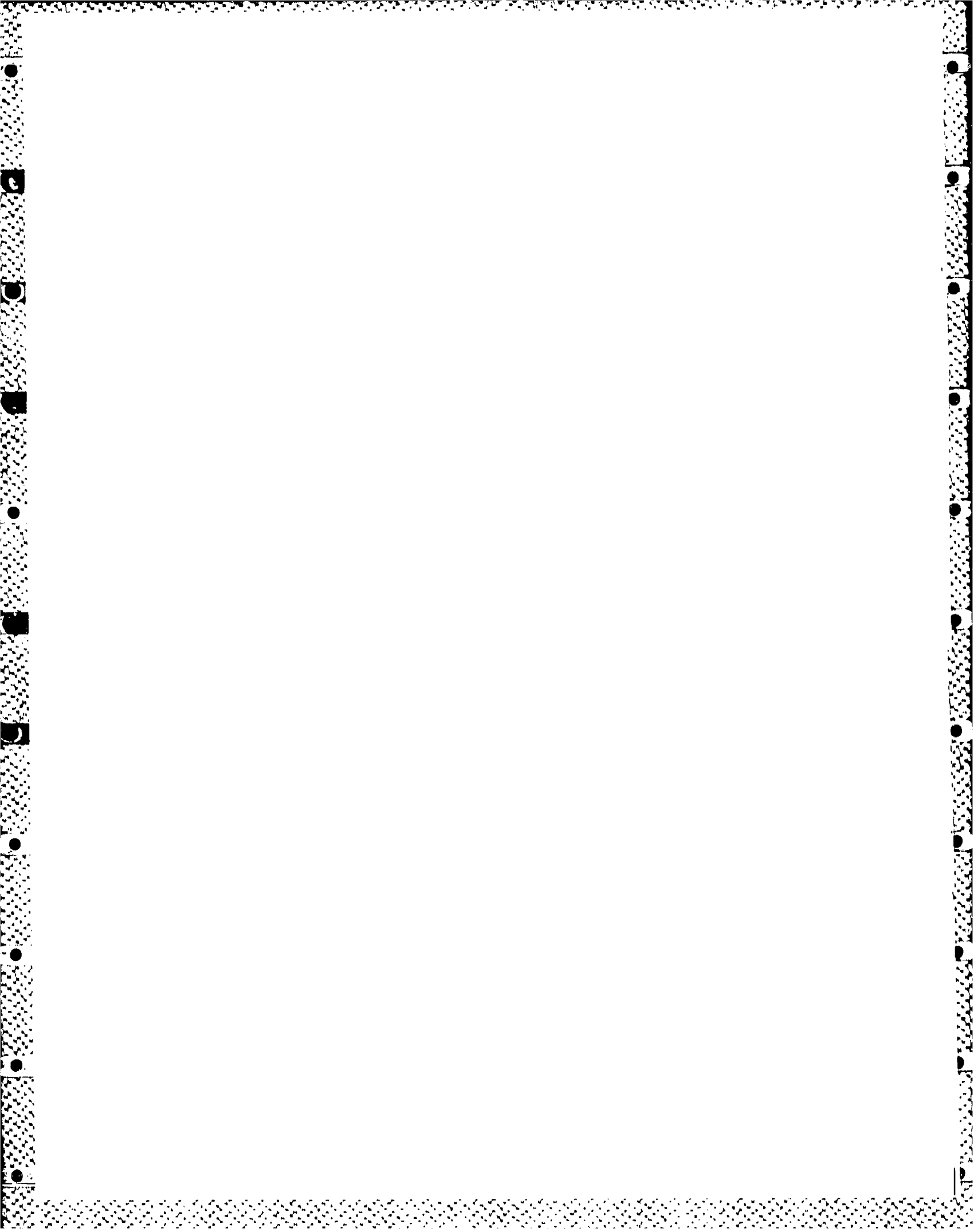
This formula must be corrected for chromatic aberration and for the plane of stationarity (POS). To correct for chromatic aberration, we simply add a constant:

$$Q = F^2 d - F + .33 \quad (2)$$

because the lens of the eye is .33D more refractive at 560 nm, which corresponds to normal lighting, than it is at 633 nm, the wavelength of the laser.

To correct for POS, we measure drum displacement from the lens to a point halfway between the drum surface and the drum axis.

To compute the dark focus value, we find the drum displacement d when the subject reports no motion in the speckle pattern and solve equation 2 for Q.



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